



# Analysis of the Effect of Mangosteen Peel Xanthone Extract (*Garcinia mangostana*) on the Quality of Smart Coatings for Beef Preservation

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**Abstract.** Beef, although a healthy source of protein, is highly perishable. The problem of decreased beef freshness is related to several processes such as the activity of various types of bacteria, biochemical reactions, and lipid oxidation. Discoloration, amino acid and fatty acid damage are the results of the decay process characterized by the formation of various volatile organic compounds, especially biogenic amines. Many cases in the community are sick because they consume beef that has decreased in quality, thus increasing attention to improve beef quality control such as smart coating packaging. On the other hand, mangosteen peel contains xanthone compounds that have strong antimicrobial and antioxidant activities and can be utilized as a packaging material in beef smart coatings. The purpose of this study was to determine the effect of mangosteen peel xanthone extract on beef smart coating in terms of antioxidant activity, antimicrobial activity and pH value. The experimental design used was a completely randomized design (CRD). The results showed that the addition of mangosteen rind xanthone extract had a very significant effect ( $P < 0,01$ ) on solubility value, transparency, tensile strength, antimicrobial and antioxidant smart coatings, but had no effect ( $P > 0,05$ ) on the pH and WVP value of smart coatings. The treatment of adding mangosteen rind xanthone extract to smart coating P3 (15%) (v/v) gave the best results with a pH value of 5.2; antimicrobial 17.15 mm; and antioxidant value of 5.12 ppm.

**Keywords:** smart coating, beef, xanthone, antioxidant and antimicrobial.

## 1 Introduction

Meat is one of the most consumed products in Indonesia, according to BPS livestock in 2023 recorded the amount of beef consumption reached 278,835.74 tons [1]. This is because meat contains many nutrients needed by the body such as protein, iron, carnosine, vitamin B, natural creatine, and minerals and glutathione. Meat contains key nutrients such as water, protein, fat, vitamins and minerals. The content of nutrients can affect the water binding capacity of meat, especially protein which has the function of binding water in meat [2]. This makes meat perishable food or easily damaged,

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because it is easily a medium for the growth of pathogenic microbes that cause damage. The high number of microbes in meat will make meat spoil quickly [3]. Easy and fast contamination by the growth of microorganisms causes a decrease in the quality of meat. This decrease in meat quality is caused by microbial contamination, which is 99% by bacterial contaminants on the surface of the meat carcass. Therefore, efforts are needed to prevent the decline in meat quality due to the activity of microorganisms. One of the efforts that can be made is the packaging method with the aim of preventing pathogenic microbial contamination of meat. Some packaging materials have natural antimicrobial and antioxidant properties or are coated with certain chemicals that can inhibit microbial growth and prevent oxidation processes in food products.

According to Nasution [4], the use of plastic packaging in Indonesia dominates with the amount of plastic packaging used reaching 53% for flexible packaging. The high use of plastic packaging is because it is cheap, easy to obtain, durable and also flexible, so people prefer to use plastic packaging materials rather than environmentally friendly packaging materials. On the other hand, the use of plastic packaging also has some disadvantages because plastic is not heat-resistant so that harmful chemicals in plastic can seep into the packaged product. In addition, plastic is also a material that is not easily decomposed (destroyed), causing waste that is not environmentally friendly. Therefore, a packaging medium that is biodegradable and safe for consumption is needed, such as gelatin-based smart coating.

Smart coating is a packaging technology for food products, can be consumed because it is made with materials that are safe for consumption, easily degraded by nature and can be an indicator if there is a problem with the product based on changes in temperature and pH marked by a change in the color of the packaging [5]. One of the materials that can be used in making smart coatings is gelatin. The manufacture of smart coatings with a single material has disadvantages, such as its brittle and hard nature, making it easy to break. To obtain a smart coating that is more elastic, the addition of plasticizers such as glycerol is required. Glycerol is a type of plasticizer that can be used in the manufacture of smart coatings, has properties that are easily digested, non-toxic, and able to increase the flexibility of packaging materials. The use of glycerol serves to increase elasticity, and according to Huri and Nisa [6], glycerol is effective as a plasticizer because it has a low molecular weight. Smart coatings can be used as packaging for products such as meat, cheese, sausages, meatballs and sweets. The application of smart coatings on several types of foodstuffs such as temperature indicators on soft drink cans, food freshness indicators on chicken and fish and ripeness indicators on fruits [7]. To improve the quality of smart coatings, an active ingredient that has high antimicrobial and antioxidant properties is required. One source of natural antioxidants and antimicrobials that has the potential to be an active ingredient in the manufacture of smart packaging is mangosteen rind.

Indonesia is a tropical country with high mangosteen production, the national statistics agency noted that mangosteen production in Indonesia reached 303,934 tons [8], this increased in 2022 mangosteen production in Indonesia reached 343,663 tons [9]. Mangosteen fruit is commonly used as a medicinal and food ingredient, this is due to the high benefits contained in mangosteen fruit. According to Susanti and

Tyaspito [10] the largest part of the mangosteen fruit is the skin by 70-75%. Mangosteen skin contains high polyphenol antioxidants such as xanthone, phenolic acid, flavonoids, catechin (including flavonoids), hexadecanoic acid, and oleic acid. Xanthone compounds are the largest antioxidants found in mangosteen rind and have antioxidant activity due to the presence of phenol groups [11]. In addition to antioxidants, mangosteen peels also contain antimicrobial compounds in the form of xanthenes that can be utilized in food ingredients such as smart coatings. The high value of antioxidants and antimicrobials in mangosteen peel is very well utilized in food additives that can inhibit lipid oxidation that causes unwanted taste changes, loss of color and food nutrients and can prevent contamination of pathogenic microorganisms that cause product damage. Based on the description above, this research was conducted with the aim of knowing the effect of adding mangosteen skin xanthone extract to smart coatings as an environmentally friendly alternative packaging so as to reduce the use of plastic packaging that is difficult to degrade by nature.

## 2 Materials and Methods

### 2.1 Materials and Equipments

The materials used for the extraction of mangosteen peel and the manufacture of smart coating are glass beaker (Pyrex), Petri dish (Anumbra), measuring cup (Herma), aluminum pan, blender (Phillips), digital scale (High Precision Kitchen Scale Accuracy 0.01 g), glass stirrer (Pyrex), 100 mL film pot, Whattman 42 paper (Cytiva), funnel (Pyrex), rotary evaporator (Iwaki Ren 1), magnetic stirrer (Joan Lab SH-2), aluminum foil (Klin Pak), digital thermometer (TP 101), measuring pipette (Iwaki), and 60 mesh sieve (Test Sieve Analysys). Materials used for antioxidant activity analysis are analytical balance, vortex, centrifuge tube, 25ml volumetric flask, measuring pipette (Iwaki), cuvette, UV-VIS spectrophotometry (721 Spectrophotometer). Materials used for pH analysis using a pH meter. Materials for antimicrobial activity analysis are paper discs, petri dishes, pipettes, beaker glasses. Materials for antioxidant activity testing is a 25 ml volumetric flask and spectrometer.

The equipments used in this study were beef, gelatin (hakiki), glycerol, distilled water, 70% alcohol and mangosteen peel. Equipments for antioxidant activity analysis using DPPH solution, methanol. Equipments for pH analysis using buffer solution, distilled water. Equipments for antimicrobial activity analysis using *E. coli* bacteria, nutrient broth, distilled water.

### 2.2 Methods

The method used in this study used a laboratory experimental method with a completely randomized design (CRD) with four treatments and four replications. The research treatments were as follows:

P0: 10 g gelatin + 6 mL glycerol

P1: 10 g gelatin + 6 mL glycerol + 5% (v/v) mangosteen peel extract.

P2: 10 g gelatin + 6 mL glycerol + 10% (v/v) mangosteen peel extract.

P3: 10 g gelatin + 6 mL glycerol + 15% (v/v) mangosteen peel extract.

The stages carried out include extraction of xanthone compounds, making smart coatings, and testing. The results obtained were analyzed using ANOVA, and if differences were found, further analysis was carried out using the Duncan Multiple Range Test.

### 2.3 Research Procedure

**Extraction of Xanthone Compounds from Mangosteen Peel.** Separation was carried out on the outer skin, inside, seeds, and flesh of fresh mangosteen fruit. The skin was then cut into 1 cm pieces and dried using a cabinet dryer at 40-50°C for 10 hours. The mangosteen peel flouring process was carried out using a pin disc mill with a 60 mesh sieve. Mangosteen peel flour was extracted using maceration method by mixing 70% ethanol as much as 1:5 into a glass beaker for 24 hours while stirring using a platform shaker. The filtering process was carried out with a filter cloth, then continued with filter paper using vacuum filtration. Solvent separation was done with a vacuum rotary evaporator at 45°C until a total soluble solids (TSS) of 20 brix was obtained [12].

**Preparation of Smart Coating.** A total of 8 g of gelatin was dissolved in 100 mL of distilled water for 40 minutes at 70°C with a magnetic stirrer to accelerate dissolution. Then, glycerol at 6% of dry weight was added to the solution, and stirred for 15 minutes. Xanthone souls were added with treatments of 0%, 5%, 10%, and 15%. The resulting solution was then poured into a plate and air-dried [13].

**Antioxidant and Antimicrobial Activity Analysis on Smart Coating.** The DPPH (1,1-diphenyl-2-picrylhydrazyl) method was used to analyze antioxidant and antimicrobial activities. Smart coating samples weighing 30 mg were immersed in 4 mL of DPPH methanol solution (100 µM). The solution was kept in a dark place at 25°C for 1 hour. The absorbance was measured using a spectrophotometer at a wavelength of 517 nm. The antimicrobial activity of the intelligent packaging was evaluated using the disc diffusion method against pathogenic strains [14].

**pH Analysis of Smart Coating.** In pH analysis, smart coating samples are immersed in a series of buffer solutions with different pH values (pH 2-13) at room temperature for 10 minutes. After that, the sample is dried on filter paper to remove excess solution [14].

## 3 Results and Discussion

### 3.1 Mangosteen Peel Xanthone Extract Yield

In the manufacture of mangosteen peel extract, 25 ml of brownish yellow extract was obtained with a percent yield of 11.62%, this result is in accordance with the standards of Farma Kope Herbal Indonesia, 2017, the requirements for a good thick extract

yield are not less than 10% so that it can be interpreted that the results of this study meet the requirements of a good extract yield [15]. The yield of an extract can be influenced by several factors, one of which is the concentration of solvent used. The higher the concentration of solvent used, the more yield is produced. The extraction process uses the principle of “like dissolve like”, namely the extraction process can occur using the same solvent, besides that the extraction process also applies the principle of mass equilibrium, namely the same level of polarity causes a component of the material to be transferred to one of the solvent phases. This interaction will continue until the mass equilibrium point between the material and the solvent is obtained. In this study, mangosteen peel simplisia powder was dissolved in 70% ethanol.

**Table 1.** Yield value of mangosteen peel extract.

Powder Weight	Extract Weight	Extract Yield
215 g	25 ml	11.62%

Ethanol is a universal solvent that can dissolve various types of active substances, both non-polar, semi-polar, and polar. In addition, the advantage of using ethanol as a solvent for extraction is that it is non-toxic, easy to obtain, and relatively cheap.

### 3.2 Solubility, Transparency, Tensile Strength and WVP Tests

The average value of the solubility of gelatin smart coating with the addition of xanthone extract can be seen in Table 2.

**Table 2.** Mean value of solubility (%) with various treatments of xanthone extract addition.

Treatment	Solubility	Transparency	Tensile Strength	WVP
P0	8.888±1.461 <sup>c</sup>	0.129±0.029 <sup>a</sup>	1.927±0.692 <sup>a</sup>	0.079±0.009
P1	6.325±0.116 <sup>b</sup>	0.591±0.020 <sup>b</sup>	1.410±0.668 <sup>b</sup>	0.061±0.008
P2	5.082±0.237 <sup>ab</sup>	0.737±0.033 <sup>b</sup>	1.082±0.756 <sup>c</sup>	0.061±0.009
P3	3.448±0.208 <sup>a</sup>	0.906±0.020 <sup>c</sup>	0.935±0.781 <sup>d</sup>	0.065±0.005

The results showed that the addition of mangosteen peel extract with different percentages of 0%, 5%, 10% and 15% (v/v) had a very significant effect ( $P < 0.01$ ) on the solubility value of gelatin smart coatings. The average value of gelatin smart coating solubility test ranged from 8.888-3.448%. It can be seen in Table 1 that the highest average solubility value was 8.888% without the addition of 0% mangosteen peel extract, namely P0, while the lowest average solubility value was 3.448% with the addition of mangosteen peel extract, namely P3. The average value of smart coating solubility tends to decrease as the concentration of mangosteen peel extract addition increases in the manufacture of gelatin smart coatings. Japanese Industrial Standard [16] states that the category of gelatin smart coating for food packaging is to have a maximum water solubility of 14%, it can be concluded that the average value of solu-

bility of all samples has met the standard. The results of the analysis of variance showed that the addition of mangosteen peel xanthone extract had no significant effect ( $P>0.05$ ) on the WVP value of smart coatings. The WVP test results have an average value of 0.07925 g/m<sup>2</sup>/24 hours to 0.06575 g/m<sup>2</sup>/24 hours. The WVP value serves to determine the coating's resistance to water and strength in resisting water ingress. Measuring the WVP value is an important factor because it can be used to extend the storage life of the product. Jafarzadeh, et al. [17] explained that the barrier properties of packaging have an important role in maintaining shelf life, by minimizing moisture transmission from the surrounding environment, so it is very important to know the water vapor permeability.

The addition of mangosteen peel extract with different concentrations had a significant effect ( $P<0.01$ ) on the transparency value of the smart coating. Based on Table 2, the highest transparency value was 0.906 mm in the P3 treatment with the addition of 15% xanthone extract, and the lowest value was 0.129 mm in the P0 treatment without the addition of xanthone extract. Transparency is the level of clarity of the smart coating [18]. Transparency can be defined as the ability of a material to penetrate light. The transparency value and transparency properties of smart coatings are not directly proportional. Smart coatings are cloudy when the transparency value is high and vice versa [19]. The transparency value increases along with the addition of mangosteen peel extract, this is due to the increase in active ingredients accompanied by the increasing number of dye particles dispersed in the gelatin edible film matrix. In accordance with research Warkoyo et al. [20] which states that transparency tends to increase along with the concentration of active ingredients; in other words, the more active ingredients added, the more the degree of clarity decreases. This is because mangosteen peel extract is red in color, so the greater the concentration of extract added will produce a film with a higher level of redness, as a result the degree of transparency decreases.

The addition of mangosteen peel extract with different concentrations has a significant effect ( $P<0,01$ ) on the tensile strength value of smart coatings. Based on Table 2, the highest tensile strength value was 1,927 mm in the P0 treatment without the addition of xanthone extract, and the lowest value was 0,935 mm in the P3 treatment with the addition of 15% xanthone extract. This is because the addition of pumpkin extract reduces hydrogen bonds in the intermolecular bonds of the smart coating matrix and reduces the tensile strength of the smart coating. Based on the Japanese Industrial Standard [16], the minimum tensile strength value for smart coatings is set at a minimum of 0.39 Mpa, and coatings containing pumpkin extract meet the coating standard. The smart coating tensile strength value shows the maximum ability of the smart coating before it breaks when receiving a load or force. The decrease in the tensile strength value of the edible film certainly affects the level of stability of the edible film in various temperature and humidity conditions, so it has the potential to easily soften, harden, or be damaged. The higher the amount of glycerol given to the smart coating, the more the tensile strength value increases, giving plasticizers such as glycerol can cause a reduction in internal hydrogen bonds and will weaken the intermolecular tensile forces of adjacent polymer chains, thereby reducing the breaking strain strength. Increasing the provision of active ingredient extracts also affects the tensile

strength value [19], this is because increasing the amount of active ingredients can increase the total soluble solids.

### 3.3 pH, Antimicrobial and AW Tests

The results show that the addition of mangosteen peel extract with different percentages, namely 0%, 5%, 10% and 15% (v/v) did not have a significant effect ( $P>0.05$ ) on the pH of the smart coating. The average value of the pH test ranged from 5.2 - 5.725 (A), it can be seen in Table 3 that the highest pH value was 5.725 (A) without the addition of mangosteen peel extract (P0), while the lowest average value was 5.2 (A) with the addition of 15% mangosteen peel extract (P3). The average value of smart coating pH tends to decrease, which means that the pH of smart coating becomes more acidic along with the addition of mangosteen peel extract. The decrease in pH of smart coatings is due to the addition of mangosteen peel xanthone extract which has acidic properties.

**Table 3.** Mean values of pH, antimicrobial and AW tests on smart coatings.

Treatment	pH	Antimicrobial	AW
P0	5.725±0.09	11.5±0.68 <sup>a</sup>	0.552
P1	5.325±0.17	13.52±0.88 <sup>b</sup>	0.573
P2	5.275±0.05	15.2±0.22 <sup>c</sup>	0.570
P3	5.2±0.08	17.15±0.97 <sup>d</sup>	0.578

In general, the pH value is closely related to microorganism contamination in meat. The low content of microorganisms affects the slower activity of microorganisms, on the other hand, the ability to change meat nutrients will also be slower. The pH value of gelatin smart coatings is influenced by the composition of the ingredients used in making gelatin smart coatings. The decrease in pH value in smart coatings is because protein-based edible coatings are a high barrier to oxygen and carbon dioxide. In addition, protein-based edible coatings can inhibit bacterial activity, which results in the inhibition of the production of non-protein nitrogen content that can cause alkaline accumulation. The pH value that is too low in smart coatings is easily overgrown by mold and yeast. Mold can grow well in the pH range of 2-8.5 but prefers acidic pH [21]. The pH value of smart coatings can be used as an indicator of spoilage in food packaging. At acidic pH conditions, microorganism activity will be inhibited by antimicrobial activity, explained by Mei, et al. [22] that the process of decay in food is accompanied by changes in pH. The rise and fall of pH values can also affect antimicrobial activity, while the optimum conditions lie in the pH range of 5-6 [23].

The results of the analysis of variance in Table 3. show that the addition of mangosteen peel extract with different percentages, namely 0%, 5%, 10% and 15% (v/v), has a very significant effect ( $P<0,01$ ) on antimicrobial smart coatings. The average value of the antimicrobial test ranges from 11.5 - 17.15. It can be seen in Table 3 that the highest antimicrobial value is 17.15 (A) with the addition of 15% mangosteen peel

extract (P3), while the lowest average value is 11.5 (A) without the addition of mangosteen peel extract (P0). The average value of antimicrobial smart coatings tends to increase, which means that the higher the concentration of mangosteen peel xanthone extract addition, the stronger the inhibition of microbial activity that occurs.

In research conducted by Kholifah et al. [24] antimicrobial activity in mangosteen peel xanthone extract against test bacteria was examined using a clear inhibition zone. The clear zone is an empty area that is not overgrown by *E. coli* bacteria and this zone is expressed as an area that can inhibit *E. coli* bacteria. The area of inhibition will show the effectiveness of the smart coating in inhibiting bacteria. The wider the clear zone can be interpreted that the smart coating has the ability to inhibit *E. coli* bacteria better [25]. The more the addition of mangosteen skin xanthone extract to the smart coating increases, the greater the clear zone or inhibition zone formed on the film. This can be interpreted that mangosteen rind xanthone extract in smart coatings as an antimicrobial on food can inhibit and prevent foodborne antimicrobial activity in maintaining food resistance.

According to Meilina and Hasanah [26], mangosteen peel extract has antibacterial activity that can act as bacteriostatic or bactericidal. Xanthone in mangosteen peel is a compound that belongs to the polyphenolic phytonutrients group, namely bioflavonoids. Although at low concentrations, bioflavonoids can poison protoplasm, damage and penetrate cell walls, and precipitate bacterial cell proteins. In addition, bacterial death can be caused by various factors, including antibacterial mechanisms that include inhibition of microbial cell wall synthesis, disruption of cell membranes, influence on nucleic acid biosynthesis, and inhibition of protein synthesis [27]. The results of the analysis of variance showed that the effect of the addition of mangosteen peel extract in smart coatings gave no significant difference ( $P > 0.05$ ) to water activity ( $A_w$ ). The test results of water activity ( $A_w$ ) have an average value of 0.552 to 0.580.

The  $A_w$  value serves to determine the coating's resistance to water and strength in resisting water ingress. The  $A_w$  value is used as an indicator of the growth of microorganisms on edibles. The test results show that the water activity ( $A_w$ ) value of smart coatings is in the range of safe values, because it has a value below the value of water activity in microorganisms.  $A_w$  value that can be used by living microorganisms such as bacteria 0.90, yeast 0.80-0.90, and mold 0.60-0.70 [28].

### 3.4 Antioxidant Test of Smart Coatings

The results of the analysis of variance in Table 4 show that the addition of mangosteen peel extract with different percentages of 0%, 5%, 10% and 15% (v/v) gives a very significant effect ( $P < 0.01$ ) on the antioxidant of smart coatings. The average value of antioxidant test ranged from 5,120 - 26,000 (A), it can be seen in Table 2 that the highest antioxidant value was 26,000 (A) without the addition of mangosteen peel extract (P0), while the lowest average value was 5,120 (A) with the addition of 15% mangosteen peel extract (P3). The higher the concentration of added pumpkin extract, the better the antioxidant activity (IC50). The value of antioxidant activity (IC50) in this study shows that the smart coating has an IC50 value of  $< 50$  ppm so that it is included in a very strong antioxidant. The P3 treatment with an IC50 value of 5,120

ppm means that the addition of 15% mangosteen peel xanthone extract has the best antioxidant activity to inhibit 50% free radicals compared to other treatments.

**Table 4.** Yield value of mangosteen peel extract.

Treatment	Antioxidant
P0	198.92±2.54 <sup>a</sup>
P1	14.15±7.34 <sup>b</sup>
P2	10.56±0.88 <sup>b</sup>
P3	5.78±0.60 <sup>b</sup>

Xanthone belongs to the polyphenol group which is one of the classes of compounds in mangosteen skin that has a role in its pharmacological effects, such as antioxidant effects [26]. Compounds with antioxidant effects play a role by inhibiting auto-oxidation which will ultimately reduce oxidative stress by reducing the number of free radicals. In addition, antioxidants also protect tissues from damage due to oxidation reactions [29]. Free radicals are atoms or molecules with unpaired electrons that are reactive, such as Reactive Oxygen Species (ROS) and Reactive Nitrogen Species (RNS) [30]. ROS including oxygen radicals such as superoxide anion ( $O_2^-$ ), hydroxyl radical (OH), and hydrogen peroxide ( $H_2O_2$ ), can trigger lipid peroxidation in products such as beef [31]. Antioxidant compounds are known to be rich in hydrogen electrons, the use of smart coatings containing xanthone compounds can reduce the formation of malonaldehyde by donating electrons to free radicals.

## 4 Conclusion

The addition of mangosteen rind xanthone extract showed a very significant effect ( $P < 0.01$ ) on the antimicrobial and antioxidant values of smart coatings with IC<sub>50</sub> values below 50 ppm, besides the addition of mangosteen rind xanthone extract gave a very significant effect ( $P < 0.01$ ) on the transparency, WVP, and tensile strength values. However, the addition of xanthone extract has no significant effect ( $P > 0.05$ ) on the pH value of smart coatings. The pH value of smart coatings has a range of 5 - 6 which indicates the optimum conditions for antimicrobial activity. The addition of xanthone extract also has no significant effect ( $P > 0.05$ ) on water activity (Aw), which indicates that the water activity (Aw) value of smart coatings is in the range of safe values, because it has a value below the value of water activity in microorganisms. In the solubility test, the addition of mangosteen peel extract has a very significant effect ( $P < 0.01$ ) on gelatin smart coatings, where the average value of smart coating solubility tends to decrease as the concentration of mangosteen peel extract is increased in making gelatin smart coatings. The use of smart coatings added with antioxidants and antimicrobials in the form of xanthone compounds can prevent lipid oxidation and microorganism contamination in products such as beef, so that packaged food products can have a longer shelf life.

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